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TITLE: RADIAL ENGINE

FIELD OF THE INVENTION

The present invention relates to engines and particularly to radial engines. It has been developed primarily for use as an internal combustion engine in which the pistons are configured to drive the crank. However, it will be appreciated that the invention is not limited to this particular field of use.

BACKGROUND OF THE INVENTION

The following discussion of the prior art is intended to present the invention in an appropriate technical context and allow its significance to be properly appreciated. Unless clearly indicated to the contrary, however, reference to any prior art in this specification should not be construed as an admission that such art is widely known or forms part of common general knowledge in the field.

There are various known radial engines. A radial engine generally has a crankshaft and pistons disposed in a radial relationship about the crankshaft. The pistons are disposed to engage the crankshaft such that there is correspondence between the rotation of the crankshaft and the reciprocating motion of the pistons in their cylinders.

In one known radial engine, the crankshaft is substituted by a crank that is configured to permit the pistons to be aligned with one another along the length of the rotational axis of the crank. As the pistons are aligned, the normal stepped-waveform crankshaft configuration cannot be used. Usually this is substituted by a cam-and-follower arrangement to permit a translation between the linear reciprocating motion of the pistons and the rotational motion of the crank. It will be appreciated that, due to the alignment of the pistons, this arrangement provides a significantly greater degree of compactness than in the case of engines where the pistons are positioned at spaced intervals along the length of the crankshaft.

However, due to the usual cam-and-follower arrangements, such radial engines have disadvantages relating to the reaction forces exerted by the cranks on the pistons, via the followers and connecting rods. Further disadvantages relate to the methods adopted for effecting suitable engagement between the followers and the cranks. For example, certain of these engines have required cranks with particularly complex structures and complex means for providing lateral support to the connecting rods. Such

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structures are expensive and difficult to produce and hence are often not suitable for large-scale production.

SUMMARY OF THE INVENTION

It is an object of the present invention to overcome or ameliorate one or more of the disadvantages of the prior art, or to provide a useful alternative.

Accordingly, the invention provides a radial engine including:

an engine block having a central aperture;

a drive shaft extending through the aperture;

a spaced pair of cam plates rotationally fixed with respect to each other, the plates being fixedly mounted on the shaft;

each cam plate including a planar face, the planar face of one cam plate opposing the planar face of the other cam plate;

the opposing faces each including a pair of spaced opposing walls defining a substantially "figure 8" shaped continuous loop, the walls on one the face being aligned with the walls on the opposing face;

at least one cylinder fixed with respect to the block and extending outwardly from the block;

a reciprocatable piston slidably mounted within the cylinder;

a connecting rod fixedly connected at one end to the piston and having an opposing free end;

a slider bearing located on the free end of the connecting rod, the slider bearing engaging with a guide for guiding the slider bearing during reciprocation of the piston; and

a cam follower engaged with the walls of each cam plate, wherein reciprocation of the piston rotates the plates and the drive shaft.

Preferably, the guide for the slider bearing is defined by a radially extending bore in the engine block and sidewalls of the bore laterally support the slider bearing during reciprocation of the piston.

Preferably, the cam follower is a pin. More preferably, the pin is included on a linear slider bearing fixedly connected to the free end of the connecting rod. Even more preferably, the slider bearing includes a prismatic body having an aperture for mounting the pin.

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Preferably each the substantially "figure 8" shaped continuous loop is defined by a groove in each the plate and the cam follower projects into each the groove.

The engine preferably includes a guide for translationally guiding the connecting rod. More preferably, the guide is defined by a complementary bore in the block, the bore having a sidewall for laterally supporting the connecting rod during reciprocation of the piston.

Preferably, the engine includes an even number of the cylinders, regularly circumferentially spaced around the periphery of the engine block.

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In another embodiment, the walls define a projecting ridge on each plate, which in turn define the loop, and the cam follower includes channels into which the ridges extend, the follower being configured to traverse the ridges to rotate the plates.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention will now be described by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a side elevation of an engine according to an embodiment of the present invention;

Figure 2 is an elevation of the engine of Figure 1 in the direction of arrow II;

Figure 3 is a side elevation of an engine block of the engine of Figure 1;

Figure 4 is an elevation of the block of Figure 3 in the direction of arrow IV;

Figure 5 is a side elevation of an engine block cover forming part of the engine of Figure 1;

Figure 6 is an elevation of the cover of Figure 5 in the direction of arrow VI;

Figure 7 is a side elevation of a further engine block cover forming part of the engine of Figure 1;

Figure 8 is an elevation of the cover of Figure 7 in the direction of arrow VIII;

Figure 9 is a side elevation of part of a crank forming part of the engine of Figure 1;

Figure 10 is an elevation of the part of Figure 9 in the direction of arrow X;

Figures 11 and 12, 13 and 14, 15 and 16, and 17 and 18, are side elevations and end elevations, respectively, of various components of the engine of Figure 1;

Figure 19 is a part-exploded perspective view of another embodiment of an engine according to the invention;

Figure 20 is a perspective view of the engine of Figure 19, shown with the cam plates removed; and

Figure 21 is a perspective view of the linear slider bearing of Figures 19 and 20.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figures 1 to 18 of the drawings and according to a first embodiment of the invention, a radial engine 1 includes an engine block 2 with a circular recess 3 on each side of the block, and a web 4 dividing the recesses. Each one of a pair of cam plates 6 and 7 is supported on a cylindrical shaft 8 (see especially Figures 11 and 12) for

rotation about an axis 9. Each plate 6 and 7 is spaced on an opposite side of the web and is accommodated in a respective one of the recesses 3. Eight cylinders 10 are regularly circumferentially spaced around the periphery of the engine block and fixedly connected to the engine block. The cylinders extend radially outwardly with respect to the axis from adjacent the plates. For the sake of simplicity, the cylinder heads and the fuel/air intake manifolds have been omitted from the drawings.

The plates 6 and 7 are substantially enclosed within the recesses 3 by a pair of engine block covers 11 and 12. The engine block 2 and the covers 11 and 12 are fixed with respect to each other by Allen screws 13 which pass through holes 14 in the covers and block. The skilled addressee will appreciate that the parts of the engine described above may be of various materials, including, where appropriate, brass, steel, or aluminium. Furthermore, the parts may, as appropriate, be cast or machined. The cylinders 10, in one embodiment, are bolted to the engine block 2, although in other embodiments the cylinders may be cast or machined to be integral with the engine block.

The engine block 2 has a circular central aperture 15. Each one of a plurality of bores 16 of generally circular cross-section extends radially from the outer rim 17 of the engine block 2 to the central aperture 15. The bores 16 are defined by sidewalls 18, and have a cross-sectional diameter greater than the thickness of the web 4. Accordingly, the sidewalls have gaps that open through the opposite outer surfaces of the web to define a longitudinal slot 19.

The shaft 8 has a cylindrical broad shaft-portion 20 and a cylindrical narrow shaft-portion 21. The narrow shaft-portion 21 is of smaller diameter than the broad shaft-portion 20 so that there is a shoulder 22 between the portions. The narrow shaft-portion 21 includes a radially outer screw thread 23 that extends from a free end 24 of the narrow shaft-portion towards a position closer to the shoulder 22.

The plates 6 and 7 are disposed to face each other with the web 4 between them. Moreover, the plates 6 and 7 are spaced apart by a spacer 25 (see especially Figures 15 and 16) that extends through the central aperture 15 of the engine block 2.

Each plate includes a pair of spaced opposed walls 26 extending from the plate surface to define a continuous loop. In this embodiment, the walls are parallel and extend into the plate to define a substantially "figure 8" shaped groove 27 in the plate, as illustrated in Figure 9. In this embodiment, the grooves are machined into or formed on their respective plates. In alternative embodiments (not shown), the plate includes a

recess, the perimeter of the recess defining the outer wall of the groove. In these alternative embodiments, a complementary second plate member fits within the aperture to define the inner wall of the groove.

In another embodiment of the invention (not shown), the walls extend outwardly from the plate surface to define a protruding continuous ridge and the cam follower includes a channel into which the ridge extends, the follower being configured to traverse the ridge as the plate rotates.

The plates are rotationally fixed with respect to each other by locating pins 28 (see Figures 17 and 18) disposed inside the perimeter of the grooves 27, such that the grooves are aligned with each other.

A locking element 32 (see especially Figures 13 and 14), having a spigot-shaped portion 33 and a nut 34, is screwed onto the screw-threaded end 23 of the narrow shaft portion 21. The nut 34 is secured against the plate 5 to hold both plates captive against the shoulder 22. In one embodiment, the plates 6 and 7 are constrained to rotate with the shaft 8 by means of a key and keyway (not shown). In another embodiment, this is achieved by means of splines (also not shown).

The engine block cover 12 has a socket-shaped portion 35 that defines a central aperture 36 through which the broad shaft-portion 8 extends as a running fit.

The other engine block cover 11 has a stepped-socket-shaped portion 37 that has a larger-diameter part 38 and a smaller-diameter part 39. The larger-diameter part 38 accommodates the nut 34 of the locking element 32. The smaller-diameter part 39 defines a central aperture 40 through which the spigot-shaped portion 33 of the locking element 32 extends as a running fit.

It will be appreciated that rotation of the plate 5 about the axis 9 is enabled by the running fits of the spigot-shaped portion 33 of the locking element 32 and the broad shaft-portion 8 in the apertures 40 and 36, respectively. In a further embodiment (not shown) the spigot-shaped portion 33 and the broad shaft-portion 8 may be provided with bearings to facilitate rotation of the plates 6 and 7. Furthermore, seals (not shown) may be provided to retain lubricant at positions where one surface rotates on another.

A reciprocatable piston 41 is slidably mounted within each cylinder 10. Each piston moves along a respective straight piston axis 42. Axes 42 each extend radially outwardly perpendicular to the crank axis 9 and lie in a common plane. One side of each piston 41 forms part 43 of a combustion chamber. On the other side of each piston 41,

there is attached one end 44 of a connecting rod 45. The connecting rods 45 extend along the complementary bores 16 in the engine block and are laterally supported by the sidewalls 18. It will therefore be understood that the connecting rods 45 are angularly immovable relative to the respective piston axes 42.

Each connecting rod 45 has an opposite free end 46 and an aperture 47 adjacent the free end. A respective cam follower in the form of a pin 48, is located in each aperture 47. Each pin 48 has opposite free ends and a central portion between the ends. The central portion of each pin is located in the apertures and the pin free ends project through the slot 19 and into the groove 27.

In use, each piston 41 is powered in a manner conventionally employed in internal combustion engines (although the cylinder heads and the intake and exhaust valves and/or ports are not shown in the drawings). The resulting reciprocating motion of the pistons 41 along their respective piston axes 42 involves corresponding motion of the connecting rods 45. It should be noted that the slots 19 extend substantially parallel to the respective piston axes 42. Thus, when the pistons 41 reciprocate, the free ends of the cam-follower pins 48 traverse the slot 19 and cammingly engage the walls 26. In the present, preferred embodiment, each pin 48 has a shoe at each of its free ends for engaging and guiding the pin along the walls 26. However, in another embodiment (not shown) each pin 48 is equipped with a roller for rolling along the walls 26.

The timing of the piston movement and the specific configuration of the grooves 27 are such that the pistons 41, via the connecting rods 45, drive the plates 6 and 7 in rotation about the crank axis 9, with the walls 26 acting as cam surfaces in engagement with the cam follower pins 48.

An alternative embodiment of the invention is illustrated in Figures 19, 20 and 21, where corresponding reference numerals indicate corresponding features. For the sake of simplicity, a two-cylinder embodiment is shown with the cylinder heads and the fuel/air intake manifolds omitted. The grooves are shown as slots extending completely through the cam plates to enable ease of understanding of the assembly.

This embodiment functions essentially in the same manner as the embodiment described above. However, in this embodiment, a linear slider bearing 50 is fixedly connected to the free end of each connecting rod 45. The bearing includes a prismatic body 51 having an aperture (not shown) through which a respective one of the pins 48 extends. Each one of the pins extends beyond the extent of the body and into the plate

grooves 28. The bores 16 in the engine block are complementary with the shape of the bearings and extend completely through the web 4 to define a slot 53. Therefore, the bores have sidewalls perpendicular to the plane of the web. This configuration simplifies manufacture of the engine block, while maintaining the lateral support for the connecting rods.

The configuration of the engine 1 in the embodiments described above is such that it is suitable for use as a two-stroke engine or a four-stroke engine.

Because the connecting rods 45 are guided in the bores 16, the lateral reaction forces exerted by the plates 6 and 7 on the cam-follower pins 48 is not communicated to the pistons 41. Accordingly there is no specific requirement for the pistons 41 to be capable of withstanding the bending moments that may occur in conventional engines. Therefore, the piston skirts present in conventional engines can be reduced in length or omitted entirely, as in the embodiment being described.

Where the engine 1 is used as the type of two-stroke engine where the fuel-air mixture is drawn into the area below the piston, because the connecting rods do not move from side-to-side as in a conventional two-stroke engine and because of the shorter or omitted skirts, a greater degree of compression can occur on the fuel-air mixture below the piston. Without wishing to be bound by theory, the applicant believes that, where a compression to 6 psi might be achieved in the case of a conventional two-stroke engine, a compression to 150 psi is achievable using an engine in accordance with an embodiment of the present invention.

Generally, if the exhaust port were lowered in a two-stroke engine of the type being discussed, this would be advantageous in one sense, as it would prolong the power stroke, with a resulting increased torque. However, in another sense, it would be disadvantageous as it would delay the evacuating of exhaust gases, which would in turn reduce the ability to transfer fuel-air mixture from below the piston to the combustion chamber. This effect would be particularly significant in cases where high engine revolution rates were required. The greater compression permitted by an engine according to an embodiment of the present invention would, however, increase the potential rate of transfer of fuel-air mixture from the area below the piston to the combustion chamber. As the resulting forcing of fuel-air mixture into the combustion chamber would also force the burnt gases out through the exhaust port, the effect of delaying the exhausting of spent gases would be offset. Accordingly, embodiments of

the present invention lend themselves to lowering the ports, with the associated advantage of longer power strokes and higher torque, without the disadvantage of reduced rate of transfer of gases.

In addition to the above, the shorter or omitted skirts would result in the pistons being lighter than those in conventional engines. The use of lighter pistons in conjunction with the radial configuration would reduce or eliminate the need for counter-weights or crankshaft bob weights which may be required in conventional engines to achieve suitable balancing. The lighter pistons would also reduce stresses, and the power losses associated with overcoming inertia.

A further advantage of the arrangement envisaged by the present invention is that the grooves 27 could be configured for each piston 41 to reach top dead centre twice for every single revolution of the plates 6 and 7 and hence of the output shaft 8. This may permit greater compactness, as the stroke would effectively be doubled without increasing the physical size of the engine.

It will be appreciated that the features of the present invention, at least in preferred embodiments, provide an effective way of achieving the cam-and-follower structure required for a radial engine of the present type. Notable among these features are the opposed walls 26 which form an integral part of the cam plates 6 and 7, the grooves 27 defined by these walls, the bores 16 in the engine block 2 and the slots 19 in the sidewalls 18 through which the cam follower pins 48 extend. These features provide a relatively simple balance between, on the one hand, the desired conversion from translational motion of the pistons 41 to rotational motion of the crank 5 with the pistons being aligned with one another for compactness, and on the other hand, effective lateral support of the connecting rods 45 and minimisation of bending moments on the pistons.

An advantage of the engine according to an embodiment of the invention is that the cylinders are arranged in opposed pairs and therefore provide for a natural balancing of the engine. It will be appreciated that, although 8 cylinders are shown in the described example, other multiples of two cylinders can be used instead.

The invention is described above as an internal combustion engine in which the pistons are configured to drive the cam plates. However, it will be appreciated that the invention is not limited to this particular application. For example, the engine may be configured so that the plates are driven by a prime mover, with the plates in turn driving

the pistons in their reciprocating motion. Such a construction may constitute, for example, a pump apparatus where each piston constitutes an individual pump.

Although the invention has been described with reference to a specific embodiment it will be appreciated by those skilled in the art that it may be embodied in many other forms.